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Fracture analysis on cage rivets of a cylindrical roller bearing

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Abstract

Some rivets used as cage linkers of a cylindrical roller bearing were fractured when an aero-engine was overhauled. Fractographic analysis, dimension re-inspection of the rivets, and metallographic analysis were performed to determine the failure cause and to offer preventive measures. The analytical results showed that the rivets fractured with a high cycle fatigue mode. The fatigue failure was mainly correlated with the fretting damage between the surface of the rivet bar and the wall of the mating hole. Based upon the rivet manufacturing and the installation process, improved measures were given to prevent such a failure.

Keywords: Cylindrical roller bearing; Rivet; High cycle fatigue; Fretting damage

1. Background

Cylindrical roller bearings are widely used in industry for their good caring capacity especially, in the radial direction. Under the conditions of heavy loading and impact force, rolling bearings with machined cages are chosen. Such a bearing is mainly composed of inner ring, outer ring, rollers, and semi-round head rivets as linkers of the cage cover and the cage seat. Contact failure and/or wear failure, the typical bearing failure modes, occur on the surface or the subsurface of raceway and rollers [1,2]. Cage failure is characterized by a wear deformation or a plastic deformation [3,4]. Little information about cage rivet failure is available in the literature [5].

Some cage rivets of a cylindrical roller bearing occurred to fracture when an aero-engine was overhauled after its 400-hours service. In the failed bearing, thirty rivets were used and ten of them were fractured. Each rivet had a cold driven head and a hot driven head. The cold driven head was installed on the upper surface of the cage seat and the hot driven head was installed on the upper surface of the cage cover. The rivet material is a ML15 steel, with a tensile fracture strength requirement of 390–540 MPa. Rivet fracture may result in parting of the cage cover and the cage seat, accumulation of the rollers, and further failures of the other bearing components. Considering that the rivet fracture had a deleterious effect on the aero-engine and that several

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bearings of the aero-engine had the same configuration as the failed one, this present paper analyzed the rivet fracture characteristics and the lateral morphology of the fracture surfaces, and re-inspected the rivet dimension and fit clearance between rivet bar and the mating hole. According to the analytical results and the rivet manufacturing and the installation process, causes and preventive measures for such a failure were given.

2. Observations

2.1. Distribution of the failed rivets

Fig. 1 shows the rivet distribution on the upper surface of the cage seat. Thirty rivets were used and ten were fractured neighboring to the cold driven head. The failed rivets are marked with solid lines in Fig. 1. Almost the failed rivets were located within the range of half circumference. The rivet bars were still kept in the mating holes. All the hot driven rivet heads were in good condition.

2.2. Fracture surfaces

Fracture occurred at the transition round angle position between the cold driven rivet head and the rivet bar. The fracture surface, perpendicular to the longitudinal axis, was the transition transverse section of the cold driven head and the rivet bar, as shown in Fig. 2. All the failed rivets had the same macroscopic fracture appearances. Fracture surfaces were in charcoal grey color. Cracks initiated from the rivet surface and there were small edges radiated from the crack origins (Fig. 3).

As shown in Fig. 3, there were two flat crack propagation zones (referred to as zones I and II) on the fracture surface. Zones I and II were in opposite directions and zone I was distinctly larger than zone II. The fast fracture area (referred to as zone III), with a rough fracture appearance, was located between zones I and II. Zones I and II accounted for about 90% of the fracture surface.

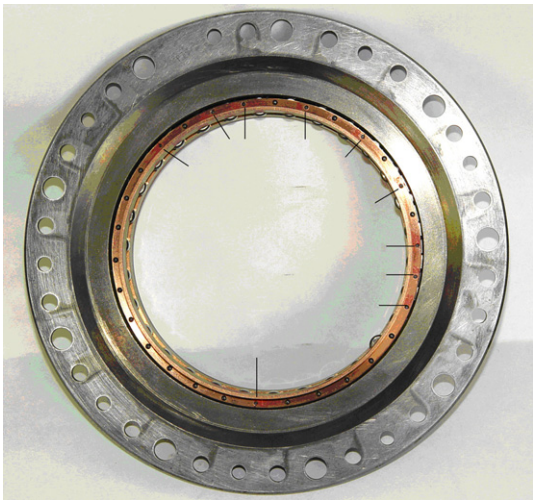

Fig. 1. Rivet distribution on the upper surface of the cage seat.

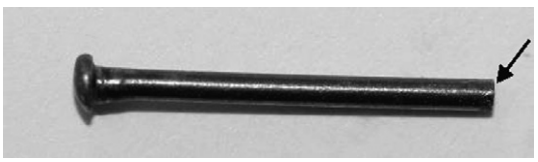

Fig. 2. Fracture position.